The Literature of Telemedicine: A Bibliometric Study

Teresa S. Welsh

ABSTRACT. A specialized body of telemedicine/telehealth literature has developed in recent years, fueled by research and the development of telemedicine as a field of study.

This bibliometric study examines the publishing and citing patterns of telemedicine literature indexed by the Telemedicine Information Exchange (TIE), an online database maintained by the Telemedicine Research Center (TRC) with major support from the National Library of Medicine. Citation counts in the TIE bibliographic database trace the growth and development of telemedicine literature and identify the most prolific authors. Citation counts in SciSearch® cited reference science database indicate the most cited telemedicine journals and authors and are used to compute journal impact factors. Seventy percent of the telemedicine literature was published since 1995; 86 percent was published since 1990. Core telemedicine journals, *Journal of Telemedicine and Telecare* and *Telemedicine Journal*, are peer-reviewed, research-oriented, highly cited in SCI®, and have a high Journal Impact Factor. The most prolific authors are not necessarily the most cited (only 30 percent of top ten most prolific telemedicine authors are also among the top ten most cited in SCI). *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com> © 2005 by The Haworth Press, Inc. All rights reserved.]*

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INTRODUCTION

The future of medicine is telemedicine

–C. Everett Koop, M.D., Sc.D. (1998)

A specialized body of literature has developed in recent years, fueled by research and the development of telemedicine as a field of study. In the past decade, telemedicine journals, magazines, and newsletters emerged, in addition to a growing number of telemedicine-related articles in the literature of other disciplines such as medicine and telecommunications. For purposes of research and collection development, it is important to examine the publishing and citing patterns of emerging fields of study to determine the most prolific authors and publications as well as the authors and publications that have the greatest impact.

Telemedicine (from the Greek *tele*, "at a distance" and the Latin *medicus*, or physician), is literally "medicine practiced from a distance." Telemedicine began with space bio-telemetry technology in the late 1950s and 1960s and grew slowly in the 1970s through the 1980s (Brauer, 1992). In the 1990s, the proliferation and lowering costs of digital telecommunications technology, as well as an increasing shortage of health professionals in rural and isolated areas, led to a renewed interest in telemedicine as a means to improve access to healthcare.

Telemedicine is defined by the Telemedicine Information Exchange as the "use of electronic signals to transfer medical data (photographs, x-ray images, audio, patient records, videoconferences, etc.) from one site to another via the Internet, Intranets, PCs, satellites, or videoconferencing telephone equipment in order to improve access to health care" (2002).

Jim Reid, author of *A Telemedicine Primer: Understanding the Issues*, defines telemedicine as "the use of advanced telecommunications technologies to exchange health information and provide health care services across geographic, time, social, and cultural barriers" (1996).

According to the *Telemedicine Report to Congress*, *January 31, 1997*, "telemedicine can mean access to health care where little had been available before . . . Telemedicine has the potential to improve the delivery of health care in America by bringing a wider range of services such as radiology, mental health services, and dermatology to underserved communities and individuals in both urban and rural areas."

This study examines the publishing and citing patterns of telemedicine literature indexed by the Telemedicine Information Exchange (TIE at http://tie.telemed.org), an online bibliographic database maintained by the Telemedicine Research Center with major support from the National Library of Medicine. TIE is a comprehensive database that includes relevant citations from MEDLINE and from other disciplines such as telecommunications.

Citation counts in the TIE database trace the growth and development of telemedicine literature and identify the most prolific authors. Cited reference counts in SciSearch® cited reference science database (accessed through http://www.dialogweb.com) identify the most cited telemedicine authors and journals and are used to compute journal impact factors.

LITERATURE REVIEW

Terminology

Bibliometrics

> The use of mathematical and statistical methods to study the usage of materials and services within a library, or to analyze the historical development of a specific body of literature, particularly its authorship, publication, and use. Prior to the mid-20th century, quantitative studies of bibliographic data and usage were known as *statistical bibliography*. (Reitz, 2002)

Citation Analysis

> A citation, the acknowledgement that one document receives from another, implies a relationship between the documents. Citation analysis is "that area of bibliometrics which deals with the study of these relationships." (Smith, 1981)

> Citing versus Cited Documents
> If Journal A contains references to
> Journal A
> Journal B
> Journal C
> Journal A *is citing* Journals A, B, and C
> Journals A, B, and C *are cited by* Journal A. (Nisonger, 2000)

Citation Analysis

Scientific citation indexing began in the post-WWII era in response to the growing need of researchers for a more efficient method of indexing and re-

trieval. Dr. Eugene Garfield (1996), founder of the Institute of Scientific Information® (ISI®), pioneered the creation of the multi-disciplinary *Science Citation Index*® (SCI®) that was inspired by the legal citation index, *Shepard's Citations*.

The classic 1981 article "Citation Analysis" by Linda C. Smith traces the development of citation analysis as a research method and discusses its advantages, limitations, and applications. Of particular interest to this study is the reference to "literature of" studies that typically include types, age, highly cited authors and journals, languages and/or countries of origin, and subject distribution.

A relevant example of a "literature of" citation analysis is Susan Davis Herring's (2000) study that examines publishing and indexing patterns of digital library literature to identify the core journals and descriptor terms. Results indicate no core journals and inconsistent indexing for this multi-disciplinary subject.

Assumptions/Limitations of Citation Analysis

While citation analysis is valued for its unobtrusiveness, preciseness, and objectiveness, it also contains an implicit set of assumptions about the nature of citations (Smith, 1981):

1. Citation implies use of the cited document by the author.
2. Citation implies that the document cited has merit or impact and that citations are made to the most relevant works on the subject.
3. Citation implies the cited and citing documents are related in content.
4. All citations are equal and are counted equally.
5. Citations are accurately indexed.

Citation Analysis of Telehealth Literature

In reviewing the body of telehealth/telemedicine literature, only one other bibliometric study was found. Brauer's (1992) article, "Telehealth: The Delayed Revolution in Health Care," analyzes telehealth article citations catalogued by the National Library of Medicine from 1975 to 1990.

Brauer categorizes telehealth literature into two main applications, telemedicine and tele-education. He defines telemedicine as "*patient-care-oriented* clinical, diagnostic and therapeutic activities" and tele-education as "*provider-oriented* services, such as access to information and linkages with other practitioners."

Before the 1990s, the growth of telehealth was stagnant, due in part to the high cost of telecommunications. Brauer reports that between 1975 and 1990 relatively few telehealth articles were catalogued by the National Library of Medicine.

This study builds on Brauer's work and examines the growth of telehealth literature through the 1990s, a decade when the lower cost of telecommunications and increased federal funding fueled a renewed interest in telehealth and telemedicine.

METHODOLOGY

Research Questions

1. What is the growth pattern of telemedicine literature since 1960?
2. What are the publishing patterns of the major telemedicine journals?
3. Which telemedicine journals are most cited, have the highest citation rates and highest impact factors?
4. Who are the most prolific authors and the most cited authors in the field of telemedicine?

Data Collection and Analysis

Methods of investigation for this study include data collection via e-mail correspondence with Nancy Brown, TIE Senior Research Librarian, and from the Telemedicine Information Exchange database and the SciSearch citation index database.

A list of the six major telehealth/telemedicine journals was obtained from the TIE Web site. The TIE database was searched by year to determine the number of published items per year; then, TIE was searched by journal and year to determine the publication pattern per journal per year.

A search for the six major telehealth/telemedicine journals in the SciSearch citation database provided citation counts that were used to calculate journal citation rates and journal impact factors.

Upon request, Nancy Brown provided a list of authors with twenty or more publications indexed in TIE (see Appendix). A search in the SciSearch citation database was performed for each of the top ten most prolific authors and the resulting citation counts were used to calculate author citation rates and author impact factors.

Telemedicine Information Exchange Database

The Telemedicine Information Exchange (TIE) has been on the Web since 1995 and contains over 10,000 citations. More than 1,000 other Web sites link

to TIE, and TIE has 5,000 visitors per month from several countries. According to the Web site, TIE is "a comprehensive, international, quality-filtered resource for information about telemedicine and telemedicine-related activities" (http://tie.telemed.org/AboutTheTie.asp).

Journal articles comprise the majority of TIE entries (93 percent), but the other formats are included, such as conference proceedings, books, book chapters, reports, theses, and dissertations. TIE includes, but is not limited to, relevant citations from MEDLINE.

The Telemedicine Information Exchange is funded by the National Library of Medicine and is maintained by the Telemedicine Research Center, a non-profit research organization based in Portland, Oregon. Their mission is to "conduct high-quality applied research into the medical applications of telecommunications technologies, in the process increasing our knowledge of telemedicine and its real-world applications. This includes clinical services research, information services, and other investigative research. TRC is supported by gifts, contracts, and cooperative agreements from a variety of sources" (http://tie.telemed.org/AboutTheTie.asp).

SciSearch Database

SciSearch Cited Reference Science Database is "an international, multidisciplinary index to the literature of science, technology, biomedicine, and related disciplines produced by the Institute for Scientific Information (ISI). SciSearch contains all of the records published in the *Science Citation Index* (SCI), plus additional records from the *Current Contents*® publications" (http:// library.dialog.com/bluesheets/html/bl0034.html).

Journals in SciSearch are "selected on the basis of several criteria, including citation analysis, resulting in coverage of the most significant publications in the scientific, technical, and biomedical literature" (ibid.).

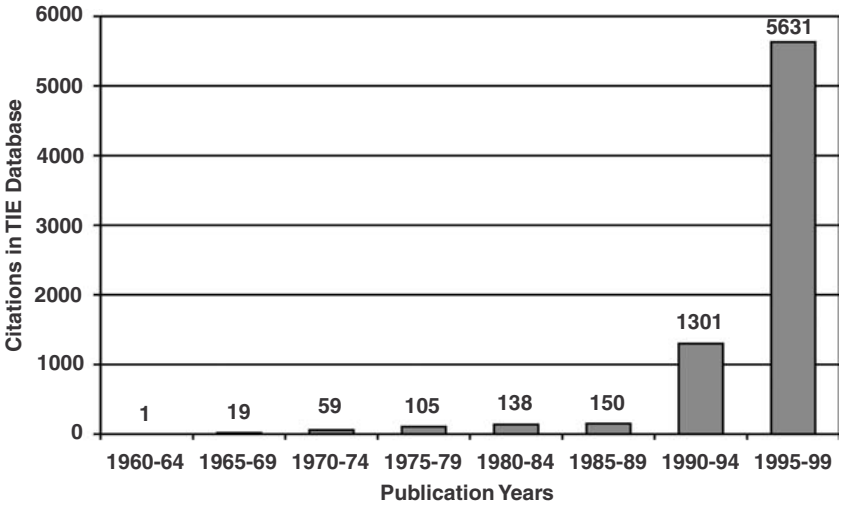
RESULTS

Literature Growth Patterns

Question 1. What is the growth pattern of telemedicine literature since 1960?

More than 8,000 citations from 1,602 journals and periodicals indexed in the Telemedicine Information Exchange (TIE) database are illustrated in Figure 1 by year of publication. This figure supports Brauer's (1992) conclusion that

FIGURE 1. Growth Pattern of Telemedicine Literature, 1960-1999



Note: Number of citations in TIE database in five-year increments

there was little growth in the literature from 1975 to 1990. As Figure 1 illustrates, 70 percent of the citations were published from 1995-99 and 86 percent were published in the 1990s.

Publication Patterns

Question 2. What are the publishing patterns of the major telemedicine journals?

Table 1 illustrates the publication patterns of the major telemedicine journals identified by the Telemedicine Information Exchange in 2002. *Telemedicine Today* began publishing in 1994; *Journal of Telemedicine and Telecare* and *Telemedicine Journal* in 1995; *Telemedlaw* in 1996; *IEEE Transactions on Information Technology in Biomedicine* in 1997; and *Telehealth* in 1998.

Mean number of journal items per year ranges from 25 items per year for *Telemedlaw* to 81 items per year for *Journal of Telemedicine and Telecare*.

Mean number of items per journal issue (number of journal items/number of journal issues) ranges from seven items per issue of *Telemedlaw* to twenty items per issue of *Journal of Telemedicine and Telecare*.

TABLE 1. Publication Patterns of Major Telemedicine Journals. Journal by Number of Citations in TIE per Year, 1994-1999 (Ranked by Earliest Year of Publication)

Journal	1994	1995	1996	1997	1998	1999	Total	Mean
Telemedicine Today	7	24	50	61	82	69	293	59
J Telemed & Telecare		37	101	76	90	101	405	81
Telemedicine Journal		37	35	30	37	121	260	52
Telemedlaw			1	16	20	37	74	25
IEEE IT BioMed				27	26	32	85	28
Telehealth					27	80	107	54
Citations in TIE	7	98	187	210	282	433	1,224	50

Note: *Telemedicine Journal* is now *Telemedicine Journal and e-Health.*
Telemedlaw is now *Telehealth Practice Report.*
Telemedicine Today and *Telehealth* are no longer published.

Journal Cited Reference Count and Citation Rate

Question 3a. Which telemedicine journals are most cited and have the highest citation rates?

While factors influencing citation vary greatly, cited reference count (the number of times a paper or journal is cited by others) and citation rate (the number of times cited by others divided by the number of papers per journal) are indicators of the impact that a paper or journal has had on their field of study.

As indicated in Table 2, the *Journal of Telemedicine and Telehealth* is most cited in SciSearch cited reference science database, with *Telemedicine Journal* the next most cited.

To determine journal citation rate, the number of cited reference counts in the SciSearch cited reference science database is divided by the number of journal items indexed in the Telemedicine Information Exchange, 1994-1999 (http:// www.isinet.com/isi/hot/essays/journalcitationreports/7.html).

Telemedicine Journal has the highest citation rate, 1.07, followed by the *Journal of Telemedicine and Telecare* with a citation rate of .99.

Journal Impact Factor

Question 3b. Which telemedicine journals have the highest impact factors?

The *Journal Citation Reports* journal impact formula is used as a model to calculate telemedicine journal impact factor, a measurement of the impact

TABLE 2. Citation Rates of Six Major Telemedicine Journals (Ranked by Citation Rate)

Journal	Cites in SCI	Items in TIE	= Cite Rate
Telemedicine Journal	277	260	1.07
J Telemed & Telecare	399	405	0.99
Telemedicine Today	76	293	0.26
Telehealth	3	107	0.03
IEEE IT BioMed	1	85	0.01
Telemedlaw	1	74	0.01

that a telemedicine journal has in a particular year. The number of a particular journal's articles cited in other journals in the SciSearch database for a particular year is divided by the sum of journal items for the two previous years (http:// www.isinet.com/isi/hot/essays/journalcitationreports/7.html).

To calculate 1999 telemedicine journal impact factors for the six major telemedicine journals, the numbers of journal items indexed in TIE for 1997 and 1998 were added. The number of times that journal's items are cited by others in SciSearch cited reference science database during 1999 was divided by the sum of items for 1997-98.

Table 3 indicates that the *Journal of Telemedicine and Telecare* has the highest 1999 telemedicine journal impact factor, 0.747; and, *Telemedicine Journal* the next highest 1999 telemedicine journal impact factor, 0.716.

Most Prolific Authors

Question 4a. Who are the most prolific authors in the field of telemedicine?

A list of authors with five or more items in TIE was requested and received via e-mail from Nancy Brown, Telemedicine Information Exchange Senior Research Librarian. The list was checked for duplicate author entries, such as Dakins, D. R. and Dakins, D., to obtain a more accurate count of items per author. The list was ranked by number of items in TIE, and, as of August 2000, there were twenty-six authors with twenty or more citations indexed in TIE (Appendix).

Nine of the top ten most prolific telemedicine authors indexed in TIE are also editors of telemedicine publications. Four of the top ten are female and six are male. There are two MDs; one PhD, DSc; one MA, MLS; and one JD, LLM. Three of the top ten most prolific authors are located in California; two

TABLE 3. Telemedicine Journal Impact Factors in 1999. Major Telemedicine Journals (Ranked by Impact Factor)

Journal	'97 Items	'98 Items	'99 Items	'97 + '98 Items	= Impact Factor
J Telemed & Telecare	76	90	124	166	0.747
Telemedicine Journal	30	37	48	67	0.716
Telemedicine Today	61	82	25	143	0.175
Telehealth	0	27	3	27	0.111
IEEE IT BioMed	27	26	1	53	0.019
Telemedlaw	16	20	0	36	0.000

in Maryland; one in Arizona, Kansas, North Carolina, Virginia, and Brisbane, Australia.

Most Cited Authors

Question 4b. Which authors in the field of telemedicine are most cited by others?

As previously mentioned, cited reference count (the number of times an author is cited by others) and citation rate (the number of times cited by others divided by the number of items per author) are two indicators of the impact that an author has had on a field of study.

A ranked author list (Appendix 1) of authors who have twenty or more items indexed in TIE was used to obtain a cited reference count (the number of times an author's works are cited by others) in the SciSearch cited reference science database (Table 4). Three of the top ten most cited telemedicine authors, A. Allen, R. Wootton, and R. S. Weinstein, are also among the top ten most prolific telemedicine authors. Four of the ten are also editors of telemedicine publications. Only one of the top ten is a female. Five of the top ten have an MD and five a PhD. Two are located in Kansas; two in Michigan; one each in Arizona, Colorado, Connecticut, Oregon, Washington, D.C., and in Brisbane, Australia.

To determine author citation rate, the number of cited reference counts per author in the SciSearch cited reference science database is divided by the number of items per author indexed in the Telemedicine Information Exchange. As indicated in Table 5, Douglas Perednia, MD, has the highest citation rate followed by Rashid L. Bashshur, PhD.

TABLE 4. Most Cited Telemedicine Authors in SciSearch (Ranked by Number of Cited Reference Counts, August 2000)

Author/Specialty/Location	Position	SCI Cites
Douglas Perednia, MD Portland, OR	Pres., Assn. of Telemedicine Service Providers Director, Telemedicine Research Center	123
Rashid L. Bashshur, PhD Ann Arbor, MI	Editor-in-Chief, *Telemedicine Journal* Dir. of Telemedicine Univ. of Michigan	73
Jim Grigsby, PhD Denver, CO	Senior Editor, *Telemedicine Journal* Research Associate, University of Colorado	62
Ace Allen, MD Overland Park, KS	President & Editor, *Telemedicine Today* Dir., Telemedicine Research, Univ. of Kansas	54
Richard Wootton, PhD, DSc, Brisbane, Australia	Editor, *Journal of Telemedicine & Telecare* Dir. of Health Research, Univ. of Queensland	52
Gary C. Doolittle, MD Kansas City, KS	Director, Telemedicine Services University of Kansas Medical Center	29
Ronald S. Weinstein, MD, Tucson, AZ	Director, Arizona Telemedicine Program University of Arizona Health Sciences Center	26
Richard Satava, MD New Haven, CN	Professor of Surgery, Yale University Medical Center	21
Pam Whitten, PhD East Lansing, MI	Director, Telemedicine Services, Michigan State University	20
Seong K. Mun, PhD Washington, DC	Director, ISIS Center, Radiology Dept. Georgetown University Medical Center	15

DISCUSSION

Of the six major telemedicine journals identified by TIE, two are peer-reviewed and research-oriented. The *Journal of Telemedicine and Telecare* and the *Telemedicine Journal* are most cited in SciSearch, have the highest citation rates, and the highest telemedicine journal impact factors. They are also the only two journals, of the six major journals, whose editors have a PhD and the only telemedicine journals indexed by ISI.

The most prolific authors are not necessarily the most cited authors. Only 30 percent of the top ten authors with the most items indexed in TIE are also among the top ten most cited authors in SciSearch.

While the technology for telemedicine has been in existence since the 1960s, it was not until the 1990s that the use of telemedicine to improve access to health care proliferated. Accompanying this increase in use has been a dramatic increase in the publication of telemedicine literature. Seventy percent of telemedicine literature indexed in the Telemedicine Information Exchange was published since 1995, and the six major telemedicine journals identified in TIE began publication since 1994.

TABLE 5. Most Cited Telemedicine Authors in SciSearch (Ranked by Citation Rate, August 2000)

Author	Cites in SCI	Items in TIE	= Cite Rate
D. Perednia	123	22	5.59
R.L. Bashshur	73	24	3.04
J. Grigsby	62	32	1.94
G.C. Doolittle	29	23	1.26
R. Wootton	52	46	1.13
A. Allen	54	71	0.76
R.S. Weinstein	26	45	0.58
R. Satava	21	24	0.88
P. Whitten	20	29	0.69
S.K. Mun	15	24	0.63

This publication pattern indicates that telehealth/telemedicine is a growing and increasingly important field of study. This emergent body of literature has implications for the future direction of healthcare delivery.

RECOMMENDATIONS

Further bibliometric study of telemedicine literature is recommended to track research trends by subject distribution. In addition, a co-citation analysis, bibliographic coupling analysis, cluster analysis, and mapping could identify and visualize the patterns of connectivity to other authors, papers, journals, and disciplines.

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APPENDIX. Authors with Twenty or More Citations in TIE Database (July 2000) (Ranked by Citation Count (n = 26))

Author Name	Location	Cite Count
Dakins, D.R.	San Francisco, CA	150
Kincaid, K.	San Francisco, CA	137
Allen, A.	Overland Park, KS	71
Linder, A.	McLean, VA	67
Schanz, S.J.	Raleigh, NC	49
Wootton, R.	Brisbane, Australia	46
Jones, E.	San Francisco, CA	45
Weinstein, R.S.	Tucson, AZ	45
Kinsella, A.	Kensington, MD	41
Siwicki, B.	Chicago, IL	38
Hostetler, S.	San Francisco, CA	35
Huang, H.K.	Galveston, TX	33
Grigsby, J.	Denver, CO	32
Dwyer, S.J.	Charlottesville, VA	31
Swartz, D.	Washington, DC	30
Whitten, P.	East Lansing, MI	29
Mitchell, P.	Surrey, UK	25
Bashshur, R.L.	Ann Arbor, MI	24
Satava, R.M.	New Haven, CN	24
Mun, S.K.	Washington, DC	24
Doolittle, G.C.	Kansas City, KS	23
Perednia, D.A.	Portland, OR	22
Chin, T.L.	Chicago, IL	22
Nixon, R.	Surrey, UK	21
Rees, P.	Surrey, UK	21
Rosen, E.	San Francisco, CA	21